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THE EARTHQUAKES IN SPAIN

EVEN the most conservative believer in the stability of Mother Earth must by this time have had his faith sorely shaken. Year after year, and month after month, we receive tidings of more or less serious shakings, varying from slight movements, such as merely set bells ringing and disturb the crockery on kitchen-shelves, to such shocks as convulse wide districts and bring with them disaster to life and limb as well as destruction to property. As if these tangible proofs of insecurity were not enough, we have learnt further that what we have been in the habit of dignifying with the name of the "solid" earth is really in a state of perpetual tremor. The thud of falling rain-drops, the patter of birds' feet, the tread of cattle, the gambols of children, so affect the ground on which we walk that the vibrations which they cause in it can be made clearly audible by the microphone and visible by the galvanometer. The position of the sun in the sky, the rise and fall of the tides, the thermometrical and barometrical oscillations of the atmosphere, produce in the outer parts of the earth corresponding pulsations, which, though not always certainly referable to their originating source, are perfectly recognisable, and can be registered by sufficiently delicate instruments. So that, instead of being on the whole a motionless, inert mass, the land is, in its way, almost as restless as the sea.

Fortunately, we are not sensible of these daily and hourly vibrations. It is only from time to time, by the news of earthquake-shocks from different quarters of the globe, that our attention is vividly drawn to the subject, and we are made to realise how little right we have to count on the continued stability of our own district. The daily tidings from the south of Spain, coming after so many recent chronicles of earthquake disaster in Europe, cannot but recall our thoughts to this subject. When the peace and goodwill of Christmas-tide were once more brightening the close of the year all over Christendom, the inhabitants of a wide tract of Andalusia were suddenly thrown into consternation by a succession of powerful earthquakes. The district most severely visited lies in the province of Granada and Malaga, and forms a parallelogram measuring about 70 miles from east to west and about 35 from north to south. The eastern part of the affected district passes into the great range of the Sierra Nevada, of which the highest peaks rise between 11,000 and 12,000 feet above the sea. Westwards, this range throws off some minor spurs, particularly the Sierras Tejada and Alhama, which curve round towards the north-west. The chief mass of the Sierras consists of crystalline schists stretching east and west, and flanked with Tertiary strata, from beneath which various Jurassic and other Secondary rocks emerge. The area of maximum destruction appears to be among the Western Sierras, and on the ground to the south and north of them.

The greatest amount of damage has been done at Alhama, which is almost entirely ruined. This little town stands nearly on the junction of the Tertiary rocks with the schists that rise into the more rugged ground of the mountains. A little to the south-east Abunuelas has also suffered severely. From that central area the shocks seem to have lessened outwards, but to have been felt most along the northern and southern flanks of the Sierras. According to one account the shocks have indicated earth-waves from south to north, with return movements in the contrary direction. Not improbably the actual focus of disturbance lies along the axis of the Sierras Alhama and Tejada. But the shocks have been felt over a much wider area. They have extended along the line of the mountains at least as far as Gibraltar in the west, though they are not recorded as having been marked in an easterly direction. Northwards, the towns and villages lying nearest to the centre of commotion have suffered most—Antequera, Loja, Granada. But far beyond these districts, terror was occasioned to the people of Cordova, Cadiz, and Seville, and the first shock was felt even at Madrid. No sea-wave has been chronicled as having affected any part of the coast, whence we may reasonably conclude that the earthquakes have not originated under the sea.

The Spanish peninsula has long had an evil reputation for the frequency, destructiveness, and long continuance of its earthquakes. In the present case the shocks are said to have begun three days before Christmas; but the first destructive wave arose on Christmas day. Since that date there has been an almost daily continuance of shocks of varying intensity. Such was also the case in the summer of 1863 along the great range of Sierras from Malaga to Alicante, and still earlier, in 1849, the same district continued to vibrate for several months.

Unfortunately, no accurate registers have been kept of these earth-tremors. Observations on earthquake phenomena made after the event, though useful so far, are now recognised as altogether insufficient to enable us to solve the problems presented by this interesting, but difficult, branch of geological physics. The establishment of self-registering apparatus, which was temporarily assisted many years ago by the British Association in the case of the simple instruments set up at Comrie in Perthshire, and which, more perfectly developed in Italy, has recently been so well inaugurated in Japan by Profs. Milne and Ewing, is the only satisfactory method of accumulating the necessary data. Until facts thus chronicled have been patiently gathered for some years in regions widely separated from each other, alike in distance and in geological structure, seismology must be content to remain very much at a stand. Of course, speculation will be as rife as ever, but cautious men of science will probably withhold their judgment until they are in possession of data of a kind that has not yet been systematically observed and registered.

But even before these data are gathered for the region of Andalusia, we can hardly doubt that fundamentally the shocks so often felt there arise from the process of mountain-making. The vibrations are propagated along the Sierras, and are felt with most violence near their flanks. They are probably in some way connected with the movements of the terrestrial crust that first started and have successively upraised the long parallel lines of mountainous ridge that diversify the surface of the Spanish tableland. Among the questions

awaiting investigation is whether any perceptible effect on the height and form of a mountain chain can be detected after its flanks have been convulsed with earthquakes; whether its rocks have been more tilted or folded or fractured. Men are usually too overwhelmed by the losses to life and property to take heed of such matters as these, and it may seem almost cold-blooded to suggest them for practical consideration. In all mountain districts much subject to earthquakes, it would be desirable to have an accurate system of levelling carried out, so that after a time of disturbance the heights could be checked. It would also be useful to have numerous photographs of cliffs and other sections where the rocks are well exposed, and where, therefore, any change of inclination, even to a slight extent, could be ascertained and measured. In regions where, as in the Karst, the earthquakes probably arise from the giving way of the roofs of underground tunnels or caverns, likewise in volcanic districts, the precautions here suggested might be of little use. But in those tracts where mountain-making is probably still in progress, they might supply us with many suggestive facts.

There is one other feature in the present Andalusian earthquakes to which allusion should be made. It has often been asserted and often denied that the occurrence of earthquakes is connected with the state of the atmosphere at the time. There certainly seems no doubt that in Europe, at least, the crust of the earth is considerably more convulsed by earthquakes in winter than in summer. When the shock of December 25th struck terror into the provinces of Malaga and Granada, the barometer, which a fortnight before had been remarkably steady, was exceptionally low and variable. Mr. George Higgin, of Broadway Chambers, Westminster, sends us an extract from a letter received by him from one of his engineers at Albox, in the valley of the River Almanzora, province of Almeria, not far to the eastward of the scene of disturbance. The writer, who was still unaware that there had been any earthquake, states that after December 19th a severe gale sprang up, lasting four days; the barometer varied from 29·28 on December 19th to 28·52 on the 27th, and continued to oscillate to such an extent that no trustworthy levellings could be made with it. A correspondent of the *Times*, writing on Sunday last, also mentions the low state of the barometer, and that the severest and greatest number of shocks continues to be felt from 5 p.m. till 5 a.m., and that since the outset, at intervals of about a week, the movement has shown a recrudescence with each return.

There has been also the usual chronicle of secondary effects from the earthquake shocks. Landslips have occurred, with the consequent disturbance of drainage. In one place a village has slid northwards about sixty feet, leaving a deep semicircular crevasse where it previously stood. The displaced ground has intercepted the course of an adjacent stream, so that a lake is forming behind the obstruction. At Periana a mass of rock and earth, disengaged from the slopes above, is said to have demolished a church and 750 houses. Among the numerous sulphur-springs of the region there has been considerable disturbance. Some of these sources, as has often been observed at Vesuvius and elsewhere, disappeared after the first shock, but in a day or two afterwards began to flow again at a higher temperature than before.

THE STABILITY OF SHIPS

A Treatise on the Stability of Ships. By Sir E. J. Reed, K.C.B., F.R.S., M.P. (London: C. Griffin and Co., 1885.)

THE stability of ships is a subject that has attracted considerable attention of late. Many disasters have happened to ships through insufficient stability, and have caused scientific men as well as practical naval architects to apply themselves to a renewed and close investigation of the subject. The result is that the ideas which till late prevailed respecting it are seen to be often superficial and incomplete, and in some cases not entirely free from error.

Sir Edward Reed has done good service in bringing out a treatise upon stability which presents the matter in a fresh, readable, and instructive form. Singularly enough this is the only work in the English language which attempts to deal exhaustively with it. Notwithstanding the magnitude and complexity of the subject, and its vast importance to all who are responsible for the wise design and safe management of ships, its treatment has previously been of a very restricted and imperfect character. The student of naval science has required to consult works which range over the wide field of naval architecture, and numerous papers that lie entombed in the published proceedings of learned societies, in order to acquire anything approaching a comprehensive knowledge of the problem of stability. Sir Edward Reed has brought together and placed into relation to each other the investigations made at various times by eminent men of the science of the subject, and the practical developments which have resulted therefrom. Among these are included the researches of French mathematicians and naval constructors, which have hitherto been but little known in this country.

The statement that a floating body, such as a ship, when laden so as to float at a given draught of water may assume any position—upright, inclined, or upside down—or it may when floating upright and in equilibrium be capsized with ease or with difficulty, according to the character or degree of the stability it may possess is the veriest scientific truism. Many may suppose it to be unnecessary, in this shipbuilding country, to make so self-evident an observation. Yet trite and obvious as it may appear when put into this form, it has been strangely, almost culpably, ignored by many who are responsible for the safety of ships. Very few exact investigations of the stability of individual ships have been made till quite recently; and even those that were attempted have frequently been imperfect and inconclusive.

The correct principles upon which the stability of ships depends were not demonstrated till the middle of the last century. Bouguer explained the properties of the metacentre in 1746, and gave a formula by which its position may be calculated. He also showed how the initial stiffness, and height of centre of gravity, of a ship may be determined by a practical experiment; this being the method of inclining vessels which is at length becoming usual in this country. Bouguer's investigations were followed up and extended by D. Bernouilli and Euler; and it was shown how the righting moments at large angles of inclination from the upright may be determined.

Atwood brought forward the subject clearly and forcibly